Gas Purging Optimizes Root Welds

Purging gas contaminants from the weld area results in quality pipe welds

BY M. FLETCHER

In circumstances where welds have to be designed to withstand stress in service, special consideration needs to be given to their metallurgy and profiles.

The mechanical properties of welds, particularly their fatigue properties, can be influenced significantly by their shape and composition. In particular, at the weld root, a positive reinforcement combined with smooth transition from weld to base metal are prerequisites to achieve optimum mechanical strength.

Good Practice

Joints of high quality between cylindrical sections such as tubes and pipes can only be made by ensuring that atmospheric gases are eliminated, and positive, smooth weld reinforcement is provided.

The presence of oxygen, and to a lesser extent nitrogen, around the molten weld can lead to wide-ranging defects. Discoloration is unsightly and in some instances might reflect metallurgical imbalance, especially with some stainless steels. Gross oxidation inevitably results in reduction in mechanical properties and can cause catastrophic loss of corrosion resistance. Nitrogen contamination can result in brittleness. Gases in the weld may give rise to cracking during or after cooling.

It is clear that a reduction in weld section at the root, as evidenced by a concave geometry, will reduce the joint strength. Perhaps not so evident, but in many applications of crucial importance is the presence of notches or cracks, which tend to appear at the weld/base metal interface. These can propagate in service and cause failure.

Basic Principles

Weld root quality when making tubular joints can be ensured by applying appropriate safeguards based on removal of air from the fusion zone by the provision of inert gas. This is achieved by gas purging, and the general principles are shown in Fig. 1.

Purging Gases

The most commonly used purging gas in Europe is commercial quality argon; in the U.S., helium is in more general use, being less expensive. For specialized applications, purging techniques using argon-hydrogen and helium-argon mixtures and nitrogen have been developed.

The materials being joined and the welding process used are two main factors in the selection of the optimum gas or gas mixture. Purge gas flow rate and pressure also need to be established, and once selected, they should be included in the formal welding procedure.

Variation in purge gas quality may arise during welding, and it may be desirable to apply continuous gas monitoring, especially to control oxygen and moisture content. For this purpose, dedicated oxygen analyzers and dewpoint meters are available commercially.

Purging Procedure

The first requirement is to provide gas entry and exit points. Gas is fed through one end seal with an exit hole at the other end to prevent an undesirable buildup of pressure. Argon has a greater density than air, and the gas inlet should be at a lower elevation than the bleed end so that air is expelled effectively from the pipe bore.

Total Purging

On small pipes and tubes, where the internal volume is small, the cost of continuous total purging may not be significant. Under these circumstances wooden or plastic discs simply taped to the tube ends will be adequate. Plastic caps employed, for example, to protect pipe ends and threads during transit are commonly used. It is most important that potential leak paths are eliminated and that any branch pipes are vented to ensure complete removal of air.

When total purging is impractical, perhaps because the pipe volume is large or because access is difficult, alternative containment techniques are available.

Water Soluble Papers and Pastes

A low-cost and effective solution to providing gas coverage is to make discs from water-soluble paper and tape them inside the pipes to be joined. They should not be placed in position until after any preweld heat treatment and be far enough apart, typically 500 mm, to avoid thermal damage during welding. Purge gas is introduced into the area between the soluble dams by means of a hypodermic tube through the weld joint line.

On small-diameter pipes, an effective dam can be produced simply by crumpling the paper and pushing it into the pipe bore. Soluble pastes are also available and can be convenient for small diameters.

On completion of the welding operation, the paper or paste can be removed by passing water into the pipe and allowing time for it to dissolve the barrier medium.

Thermally Disposable Barriers

Water-soluble products are not always acceptable, and an alternative method is to use cardboard discs. These are simply

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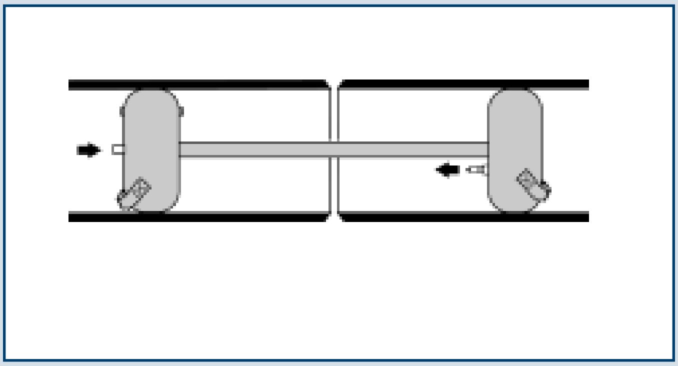

Fig. 1 — Schematic of a setup for purging.

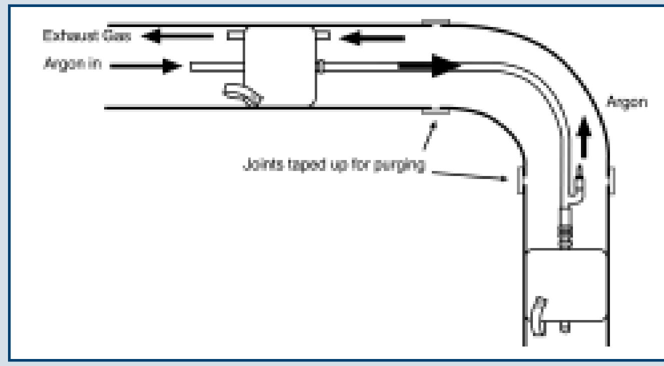

Fig. 2 — Purging a 90-deg bend.

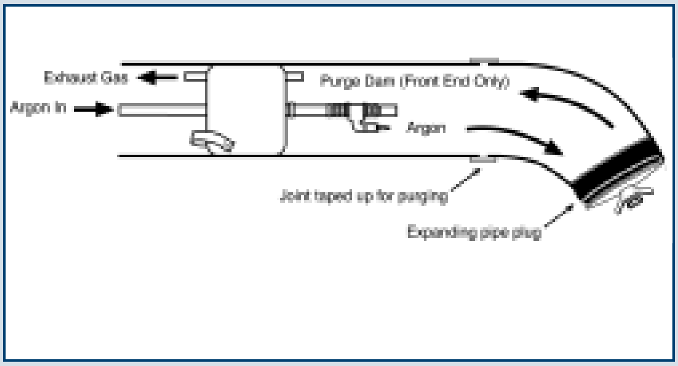

Fig. 3 — Purging a short elbow.

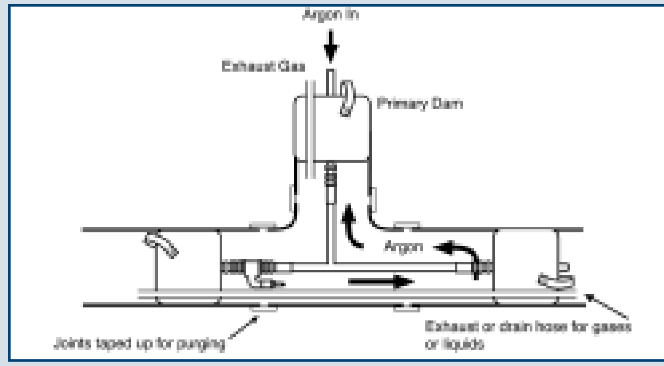

Fig. 4 — Purging a Tee piece.

cut to fit the internal diameter of the pipe and, if necessary, taped in position to provide a gas seal. The distance between discs should be typically 500 mm to avoid thermal damage during welding.

The thermally disposable disc solution is convenient if welding is to be followed by a postweld heat treatment cycle since the card is removed effectively by incineration. Otherwise, general heating by torch is a sound method of removal.

The water-soluble and thermally disposable barriers are expedient solutions where access to the tube or pipe bore is impractical after welding. If access can be gained, several alternative purge gas damming techniques, which include collapsible discs, rubber gasket discs, and inflatable bladders, can be considered.

These dams are normally placed in the pipe at the time of joint assembly, the recovery cord or rod projecting down the access route. A spacing of 150 to 200 mm will usually prevent thermal damage during welding, but it should be noted that greater spacing is prudent if preweld heat treatment is to be applied.

Table 1 — Purge Times for Various Pipe Diameters and Flow Rates

Purge Times for Gas Tungsten Arc Welding of Steel Pipe

Pipe Diameter		Flow Rate		Purge Time	Vent Diameter	
in.	mm	ft^3/h	L/min	min	in.	mm
3	75	20	10	3	1/16	1.5
4	100	20	10	3	1/16	1.5
5	125	20	10	5	1/8	3
6	150	20	10	6	1/8	3
8	200	25	12	8	1/8	3
10	250	25	12	13	1/8	3
12	300	30	15	13	1/8	3
14	350	30	17	16	—	—
20	500	35	17	25	—	—

Note: Purge time and flow rates were those required to reduce the oxygen to 1% or less, based on enclosure of 12 in. (300 mm) in length. When enclosure exceeds 12 in. length, increase flow time proportionally.
Upon completion of purging cycle, reduce flow rate to maintain slight positive pressure during welding.

Collapsible Disc Barriers

Discs can be made from any rigid sheet material; plywood is a good medium if in-house manufacture is planned. The discs are split across the diameter and hinged and a sealing pad of synthetic foam bonded to the periphery. Cords attached to the discs are used to collapse the dam after welding and to remove the discs from the pipe.

Rubber Gasket Dam

A rubber disc can be sandwiched between a pair of wooden or metal discs and some adjustment to diameter can be effected by applying axial pressure. This gasket technique is not collapsible, and after welding the discs must be pulled out past the weld root, an operation which may cause difficulties.

Inflatable Bladder Dam

An efficient purge gas containment method is to use inflatable dams such as the Argweld system. This has been developed specifically to provide a reusable solution to gas purging. It is easy to use and

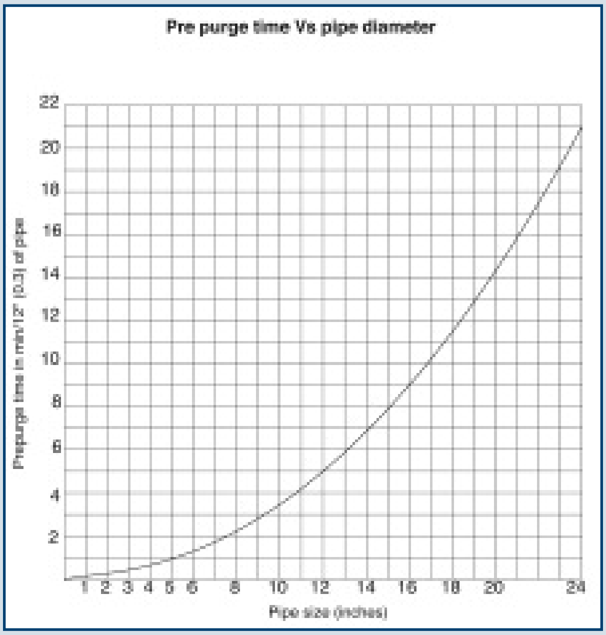

Fig. 5 — Prepurge time vs. pipe diameter. Time is for a 12-in. pipe at a flow rate of 50 ft^3/h (23.5 L/min). To calculate the prepurge time for any length of pipe, multiply the value obtained from the chart by the length of pipe. For example, find the time for prepurging 200 ft (60 m) of 5-in. (127-mm) pipe. From the chart, it takes 1 min to purge 12 in. of a 5-in. pipe. Hence, it takes 200 min (3 h 20 min) to purge 200 ft of 5-in. pipe.

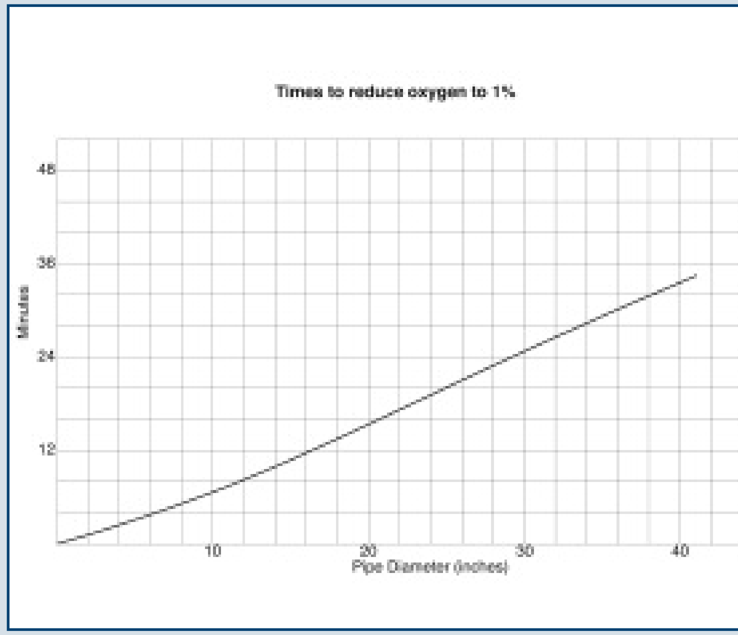

Fig. 6 — Time to reduce oxygen content to below 1%.

economical when several similar joints need to be produced.

The bladder, which has sufficient length to ensure sound sealing, is manufactured from rubber with a protective canvas cover. One is placed on each side of the joint and inflated using either compressed air or the purge gas itself. The latter is much preferred since it overcomes any problems that might arise from leakage of the bladder. Figures 2–4 illustrate the bladder concept. Variations on the basic equipment are commercially available.

Purge inlet and outlet pipes can be incorporated in the bladder to allow the full circumference to seal against the pipe wall.

High-temperature covers can be provided to afford protection during weld preheat cycles, and single bladders can be used for closed end joints. Inflation and purging gas pressures can be separately controlled.

Longer or shorter spinal connecting tubes are available, and provision can be made for continuous alteration in gas flow rate up to 20 L/min.

The Prepurge Process

A prepurge is used to displace air present in the pipework system or dam volume. Numerous factors control the prepurge time such as pipe diameter, purge volume, and maximum permitted oxygen level. A common misconception is that increasing the purge flow rate will reduce the purge time. This is a fallacy. An increase in flow rate increases turbulence and results in unwanted mixing of purge gas and air and can actually extend the purge time.

As a general rule, the prepurge flow rate and time should allow for about five volume changes in the pipe system or dam volume, but a typical gas flow rate will be in the region of 20 L/min. Figure 5 is an illustration of the relationship between prepurge time and pipe diameter based on a pipe purge length of 300 mm. For different purge lengths, it is reasonable to use a prorata calculation. Table 1 presents examples of purge times for different pipe diameters and flow rates.

Weld joints that require a root opening or have poor fitup, both of which characteristics provide an unwanted leak path for the purge gas, can be sealed by taping.

Oxygen and moisture levels in the purge gas should be checked using appropriate equipment with checking taking place at the outlet point. Where dam inserts are being used, the outlet point needs to be extended with a flexible pipe to a convenient access position. If this is impractical, a system that has the purge inlet and outlet in the same dam unit should be used.

Figure 6 gives times to reduce the dam volume oxygen content to below 1% using inflatable bladders. While 1% residual oxygen is a suitable working level for materials such as stainless steels, the level needs to be as low as 20 ppm when welding the more sensitive alloys based on titanium and other reactive metals.

The Weld Purge Process

Once the quality of the gas in the dammed volume has reached the required level, gas flow can be reduced to about 5 L/min for the welding operation. On a more practical level, it should just be possible to feel the gas flow from the exit point. Excessive flow can cause the internal pressure in the pipe to rise and create concavity in the weld root geometry and in more extreme cases can cause complete ejection of the molten weld pool.

To restrict leakage on joints not fully sealed, a higher flow rate will be necessary to avoid contamination. Toward the end of the weld run, however, as the joint becomes permanently sealed, the gas flow rate will need to be reduced to avoid overpressurization. ◆